

SURVEY OF USER NEEDS AND THE IMPACT OF PARKING PRICES ON DRIVERS' MOTIVATION TO USE PARKING SPACES IN THE CAPITAL CITY OF PRAGUE

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ABSTRACT. The paper deals with the possibilities of implementing dynamic tariff regulation of on-street parking spaces in the capital city of Prague. Achieving optimal results is conditioned by the implementation of advanced technologies, but at the same time, the dynamic tariff regulation must follow the applicable legislation and, above all, be accepted by drivers. For this reason, the paper briefly discusses the technical and legislative possibilities of implementation, and most attention is paid to the conducted survey of user needs. The survey investigates the impact of parking prices on drivers' motivation to park their vehicles in the area.

KEYWORDS: Parking, on-street parking, dynamic tariff regulation, parking survey.

1. INTRODUCTION

The issue of parking in the urban street network with a focus on appropriate regulation of static traffic is very topical. Most cities are seeking to introduce smart parking systems to make more efficient use of existing parking spaces, optimize turnover rates, reduce the number of vehicles whose drivers are looking for a free parking space, introduce more effective monitoring of payment discipline and collect traffic data with subsequent processing. This data provides an important basis for traffic planning and parking control. Smart on-street parking in the case of tariff regulation means favoring parking areas where it is desirable to increase the concentration of vehicles.

According to modern parking concepts, the main objective of introducing smart systems is to make more efficient use of existing parking areas, without the need to build new areas. At the same time as the introduction of modern technologies, organizational and control processes need to be optimized; monitoring the evolution of parking habits over time is very important for feedback and future planning. The regulation of static traffic needs to be continuously adjusted and changed according to the evolution of the behaviour of vehicle drivers. Dynamic regulation is currently referred to as the most advanced method of optimizing parking in urbanized environments and this issue is also discussed in academic literature.

Geva et al. [1] concluded from simulations that although both distance from the destination and price play a role in finding a free parking space, price was the more important of the two parameters. When the prices for “on-street” parking were comparable to those in parking lots, parking lots were chosen much more quickly. The authors concluded that if parking prices in high demand locations were on par with park-

ing lot prices, drivers would be more likely to choose to park at a greater distance from their destination or to choose parking lots more quickly.

Based on their results, Kurek and Macioszek [2] recommend the use of systems to navigate to available parking spaces. In their research, such a system led to a positive subjective evaluation of parking. According to the authors, information from sensors used to detect parking space occupancy can be used to dynamically set parking prices or to create a parking reservation system.

Aljohani et al. [3] study propose to focus on the selection and design of transport management tools through a market perspective, where transport is viewed as an allocation of resources and services. They believe that in this way it is possible to identify appropriate tools for transport management.

It is similar with navigation systems and new technologies such as C2x and sending the necessary data directly to the vehicle for guidance on a free parking space. In the public space of cities, suitable parking spaces are decreasing and to eliminate the search for a free space, the constant burden on road traffic with vehicles looking for a space, navigation and reservation of a free space is an important element of the parking solution together with a defined dynamic tariff during the daily and weekly periods [4–7].

The aim of the paper is to analyze the realistic implementation of dynamic tariff regulation of parking in the Capital City of Prague suitable for optimizing the distribution of vehicles in the street network. The results will be evaluated especially in terms of deployment of dynamic regulation in real operation as a tool for optimization of vehicle movement and parking in the urban street network. A prerequisite for a successful design is at the same time a survey of user needs, as the human factor is a key factor

Zone	Number of parking spaces	Share of PPZ
Blue – residents	76 614	64 %
Purple – mixed	42 325	35 %
Orange – visitors	1 123	1 %
Total	120 062	

Note: Data from 2020-08-18.

TABLE 1. Number of parking spaces and PPZs capacity [8].

Owner of vehicle	Number of owned vehicles	Tariff zone	Price		
			1 year	½ year	¼ year
Resident	1. vehicle	all	1 200 CZK	600 CZK	300 CZK
	2. vehicle	all	7 000 CZK	3 500 CZK	1 750 CZK
	3. and next vehicle	1	36 000 CZK	20 000 CZK	10 000 CZK
		2	30 000 CZK	17 000 CZK	8 500 CZK
		3	24 000 CZK	13 500 CZK	7 000 CZK

TABLE 2. Parking prices for residents according to tariff zones [9].

determining the functionality of the solution. Tariff regulation must be set in such a way that it provides sufficient incentive, but at the same time the rules are respected, and parking fees are paid.

The paper briefly describes the current parking management in Prague and evaluates the possibilities of implementing dynamic parking regulations. It also presents the results of a survey of user needs focused mainly on the willingness to pay parking fees. Finally, the direction of further research development is outlined.

1.1. CURRENT PARKING MANAGEMENT SYSTEM IN PRAGUE

The regulation of parking in the territory of the capital city of Prague is solved by means of paid parking zones (PPZs). The purpose of introducing PPZs is to increase the chance for residents of the busiest areas to park their cars within walking distance from their homes (or properties/businesses). The zones are being established gradually from the historical center to the periphery, the first zone was introduced in 1996, according to the new (currently valid) concept, the PPZs in Prague have been introduced since 2016, so far, the last extension was planned for July 2021 [10].

There are 3 basic parking regimes in the zones:

- Resident mode (blue zone) – residents, subscribers and property owners in the area;
- Mixed mode (purple zone) – residents, subscribers, property owners in the area and visitors;
- Visitor mode (orange zone) – short-term parking for anyone.

The grantor of the PPZs is the Capital City of Prague according to the Zákon o pozemních komunikacích č. 13/1997 Sb. The administrator is Tech-

nická správa komunikací. In Prague, modern technologies are introduced for payment of parking fees directly at the parking meter or via the MPLA web application – Virtual Parking Hours. The system enables the use of new payment channels and payment technologies, the aim is to modernize and simplify the issue of parking permits, possible sanctions and increase control. It also has the advantage of devolving the resolution of parking violations and their revenue to the boroughs, leading to higher motivation for staff to deal with violations.

Table 1 shows a summary of the number of parking spaces in each zone and the percentage of zones by zone type.

The areas of the capital city of Prague in which PPZs can be established are defined in the Regulation No. 10/2020 Coll. of the Capital City of Prague from 1st June 2020.

Each parking zone has its own operating hours, usually from 8:00 to 20:00, which can be adjusted for each specific location. Outside the operating hours, parking in the zones is not regulated. Unless the zone operating hours are indicated on vertical signage, the regulation is valid 24 hours a day. The validity of the parking permit is checked on the basis of the vehicle registration number, automatically by means of a monitoring system.

For the purposes of determining the fees, PPZs in capital city of Prague are divided into 3 tariff zones depending on location. Basically, areas in the city center and other busy areas are included in the 1. tariff zone, which is the most expensive, whereas the more peripheral city areas are included in the 3. tariff zone, which is the cheapest. Basic parking prices are shown in Tables 2 and 3. Table 2 shows prices valid for residents – these depend on the number of

Owner of vehicle	Price per 1 hour
Ordinary visitor	1. tariff zone 80 CZK, 3.20 €
	2. tariff zone 60 CZK, 2.4 €
	3. tariff zone 40 CZK, 1.6 €

TABLE 3. Parking prices for visitors according to tariff zones [9].

vehicles owned. Fee for the first owned vehicle is significantly lower than fee for third and subsequent vehicle. Table 3 shows parking fees valid for visitors to PPZs and their differences in relation to different tariff zones.

In addition to the existence of the PPZs, another important factor influencing the driver's choice of parking space is accessibility of locations by public transport and the cost of public transport fees. Prague has a very dense network of public transport stops and for a significant number of people this may be a reason to prefer public transport rather than their own vehicle.

2. IMPLEMENTATION OPTIONS

The paper deals with the evaluation of the realistic implementation of dynamic tariff regulation in the conditions of the capital city of Prague. Initially, the technical and legislative possibilities of implementing the proposed system in practice are briefly described.

2.1. TECHNICAL POSSIBILITIES

Long-term parking permits are issued electronically, as are short-term permits. The following two payment channels can be used to pay the fee for a short-term parking session [11]:

- Flowbird parking meters;
- Web-based virtual parking meter application.

Technical parameters of parking meters are very difficult to obtain from openly available sources. The most information can be obtained from the technical conditions of the contracting authority, which defined the parameters and operation for the public contract for the operation of parking meters in paid parking zones [12].

The monitoring center must have the capacity to connect a total of 1500 parking meters. The availability of the parking meter service shall be at least 98 % and the functionality shall be at least 95 %. In addition, incident groups are defined according to priority. The data connectivity shall use publicly available commercial communication networks and ensure the interconnection of all devices with the monitoring center. Precise requirements for payment acceptance, appearance, features, amenities, printed content on the parking ticket, etc. shall be defined. Drivers shall enter the registration number of their vehicle into the parking meters. The data link requirements are not adapted to the possibility of frequently uploading new

parking prices or even updating them during the day [12].

2.2. PARKING LEGISLATION

The capacity and form of parking facilities are determined by the Prague Building Regulations. Parking capacity is dealt with in §32, §33 focuses on the form and character of parking. The purpose of the parking regulations is to define minimum parking requirements according to the type of location, building type and connection to public transport, but also to set maximum permissible values.

A map of the city's zones for the purpose of determining the number of parking spaces is available on the website of the Institute of Planning and Development of the City of Prague (on the provisions of Section 32(2)).

Ordinance No. 26 on General Technical Requirements for Construction in the Capital City of Prague, Article 10 of 19 October 1999 sets out the Dispersal Areas and Facilities for static Traffic. Areas intended for a larger number of vehicles are supplemented with greenery, especially trees. Five basic criteria are considered to determine the number of parking spaces:

- Zones 1 to 4;
- Metro station catchment area;
- Territorial influence coefficient K_u ;
- Coefficient of traffic serviceability of the area K_d ;
- Indicators of the basic number of parking spaces depending on the functional use of the building.

Annex No. 2 to Decree No. 11/2014 Coll. 11.11 of the City of Prague contains a table setting out the basic number of parking spaces. The basic number of parking spaces indicator defines the gross floor area per 1 parking space. The percentage of tied and visitor parking spaces is determined [10].

Prague Building Regulations define parking capacity and the form and nature of parking. Parking for buildings is stipulated as the minimum required, and the maximum permitted number of parking stalls. It is calculated as a per cent of the basic number of stalls. Dedicated residential parking must usually be located in garages or stacked parking systems. Visitor parking must be publicly accessible, but its use may be controlled. Surface parking lots are planted with trees, generally one tree must be planted per eight stalls in the parking lot [13].

Strategic Plan of City of Prague formulates a common vision for the city. It determines the principal

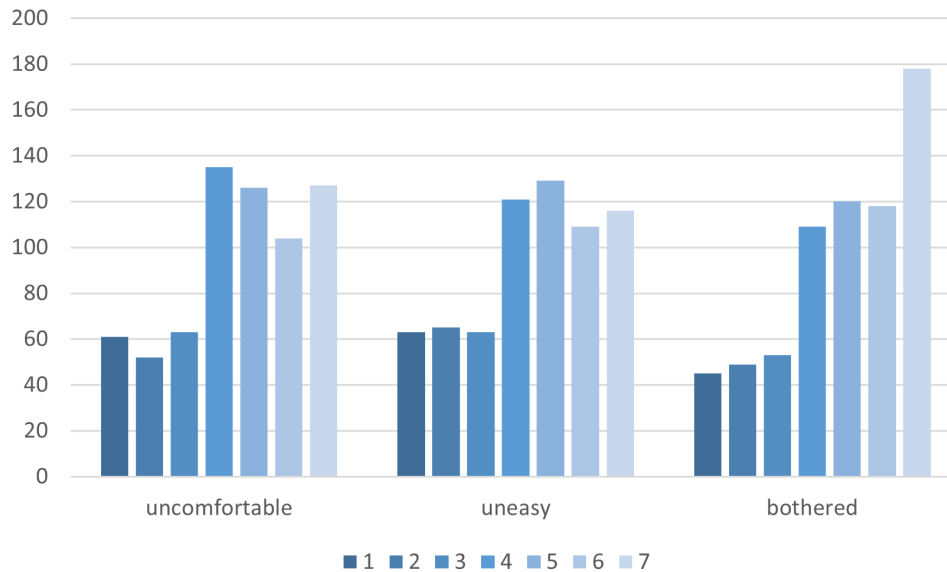


FIGURE 1. Feelings while searching for a parking space [1].

development direction in the medium- and long-term and sets out the social and economic objectives for the city. The main points relating to parking are: prioritise environmentally friendly forms of transport, i.e., walking, cycling and public transport; green infrastructure support; make public transport more attractive – the aim is to increase the share of public transport, walking and cycling above 70%; construction of new suburban P+R and B+R parking systems; increase the use of ITS in traffic control; extension and optimization of PPZs using ITS including dynamic navigation [14].

The Sustainable Mobility Plan for Prague and its Suburbs presents an overall view of transport solutions in the capital city. The vision is long-term sustainable mobility, based on a high-quality and accessible integrated public transport network based primarily on rail transport. Other preferred modes of transport are walking and cycling. Car traffic will be regulated in line with the vision, in the form of urban tolls, parking policy and preference of public transport. The parking policy will go the way of unifying the rules of parking zones, favouring eco-friendly vehicles when parking in the zones and shrinking individual parking zones so that it does not make sense to use the car for journeys within one zone. As part of the revitalisation of the urban space, the number of parking spaces will be reduced in favour of infrastructure for pedestrians, cyclists and public transport. Conversely, the plan is to develop the P+R and B+R car park network into a high quality and comprehensive catchment system [15].

2.3. USER ACCEPTANCE – QUESTIONNAIRE METHOD

The basic prerequisite for the functionality of the proposed solution is, in addition to the necessary compliance with applicable parking legislation and

technical support, the acceptance of this solution by the users (drivers). The aim of the survey was to determine the willingness to pay parking fees – the effect of parking prices on drivers' motivation to park their vehicles in a given area or neighborhood.

The survey of user needs was carried out in the form of a questionnaire survey. A questionnaire created in MS Forms was used and distributed online. The questionnaire was designed to cover all relevant aspects affecting drivers' parking behavior.

The questionnaire focused on collecting information from the following areas: statistical information specifying the respondent's personal characteristics and his/her general traffic behavior, more detailed information on the respondent's mobility and daily traffic behavior, and information on the willingness to pay parking fees. As the whole study works with the area of the capital city of Prague, the questionnaire focused both on journeys to/from Prague and on journeys around Prague. The questionnaire was distributed in two rounds.

3. FIRST ROUND OF THE QUESTIONNAIRE

The aim of Round 1 was to use open-ended questions to specify the issues so that appropriately worded closed questions could be used in Round 2. For participation in Round 1, a shortlist of selected respondents was pre-selected to represent groups with potentially different transport behavior.

Parking issues in the Czech Republic were also discussed in the paper [1]. Respondents were among others asked to rate the statements about their feelings connected to searching for a parking space and parking. The following bar graphs (Figure 1) show the perceived issue of finding a parking space and then the parking itself in the Czech Republic.

Gender	Age category	Occupation	Permanent residence
Man	9 Up to 29 years	6 Employed	12 Prague
Woman	4 30–39 years	6 Student	1 Other
	40–49 years	1	6

TABLE 4. Demographic distribution of respondents to Round 1 of the survey [11].

Gender	Age category	Occupation	Education	Residency
Man	236 Up to 29 years	216 Maternal/Parental leave	4 Elementary	2 Prague
Woman	112 30–39 years	64 Unemployed	1 High school	163 Other
Do not want to share	3 40–49 years	43 Employed	187 University	186
	50–64 years	22 Student	157	
	65 years and more	6 Housewife/husband	1	
		1 Retired	1	

TABLE 5. Sociodemographic data [11].

3.1. EVALUATION OF THE FIRST ROUND

Thirteen respondents took part in the first round of the survey and their demographic distribution can be seen in (Table 4) below. Respondents answered 17 questions relating to their transport behaviour, of which 8 were open-ended.

The results, especially the results of the open-ended questions, were used to construct the final (second round) questionnaire.

4. SECOND ROUND OF THE QUESTIONNAIRE

The wider public was invited to participate in Round 2. The main round of the survey contained a total of 28 closed questions, which were built on each other and were based on the answers of the respondents. The questions were divided into the following interlinked sections:

- Statistical information;
- Mobility and transport behaviour;
- Willingness to pay for parking and acceptable amounts;
- Parking preferences.

There were 351 respondents.

4.1. EVALUATION OF THE SECOND ROUND

First, the respondents were asked about several statistical information, the evaluation of these questions is in Table 5.

The questionnaire was completed by 309 respondents who hold a driving license. These respondents were able to continue to next parts of the questionnaire.

The results of the questionnaire showed a correlation between the commuting time from the place of residence to Prague and the frequency of commuting. Frequent commuting (daily or weekdays) increases the proportion of shorter commuting times. On the other hand, there was no correlation between the possibility of unpaid parking and the use of long-term coupons for travelling by public transport in Prague.

Figure 2 shows the evaluation of the question of car use for trips to and in Prague. The numbers of responses are shown. The chart includes the responses of all respondents who answered these questions – i.e., respondents residing in Prague and outside of Prague. It can be seen that the distribution of car use is very similar for trips to and in Prague.

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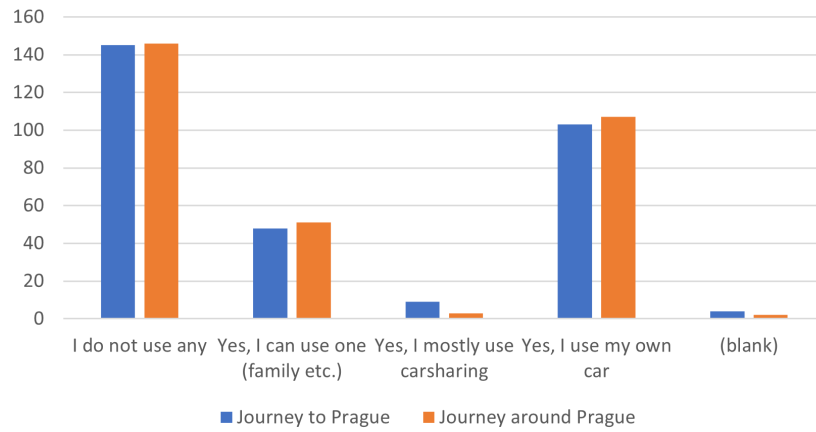


FIGURE 2. Use of the car.

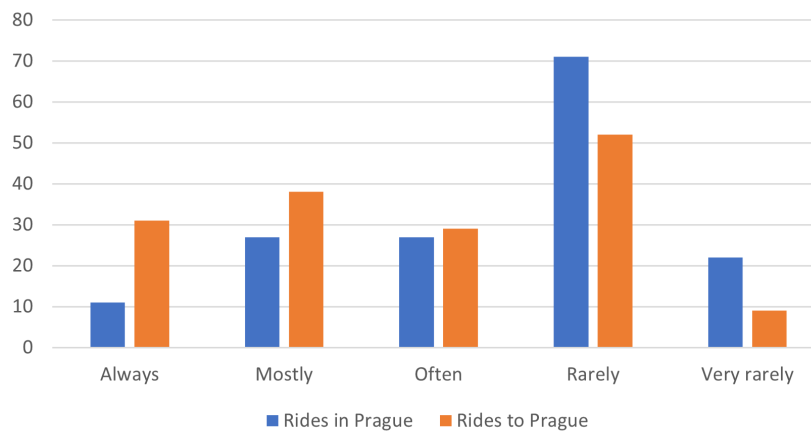


FIGURE 3. Frequency of car use.

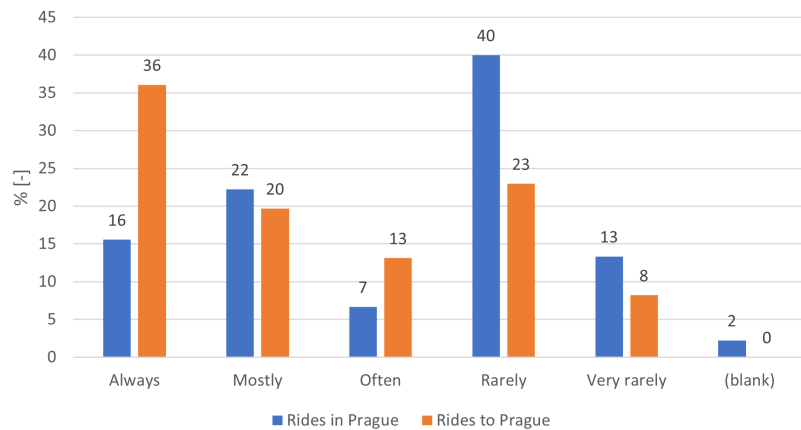


FIGURE 4. Frequency of car use, respondents residing outside Prague.

questions – i.e., respondents residing in Prague and outside Prague. The graph shows that the car is more often used for trips to Prague than for trips inside Prague.

Figure 4 uses only responses of respondents living outside Prague. For these respondents, the car is used with high frequency for trips to Prague. A total of 56 % of respondents chose the answer “always” or “mostly”. On the other hand, the car is used rather less frequently for trips inside Prague. The answer ‘rarely’

or ‘very rarely’ was chosen by 53 % of respondents.

The results of the next part of the questionnaire survey are crucial for the further continuation of the research, as they indicate what price drivers are willing to pay for one hour of regular parking in Prague. Normal parking is defined as payment for 1 h of parking under normal circumstances, i.e., not an isolated payment that drivers are willing to pay exceptionally or in urgent cases (such as parking near a hospital) and the amount is a one-off.

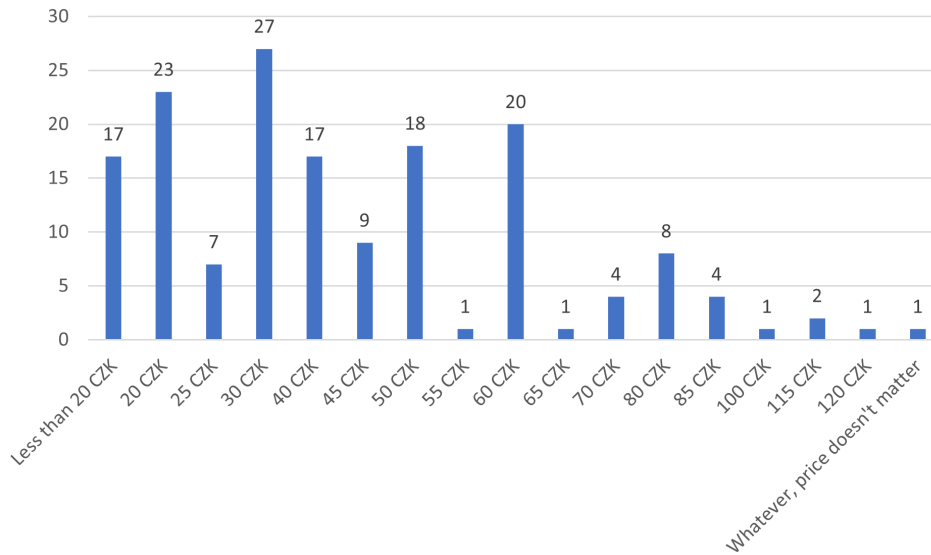


FIGURE 5. Maximum accepted parking fee for 1 h of parking.

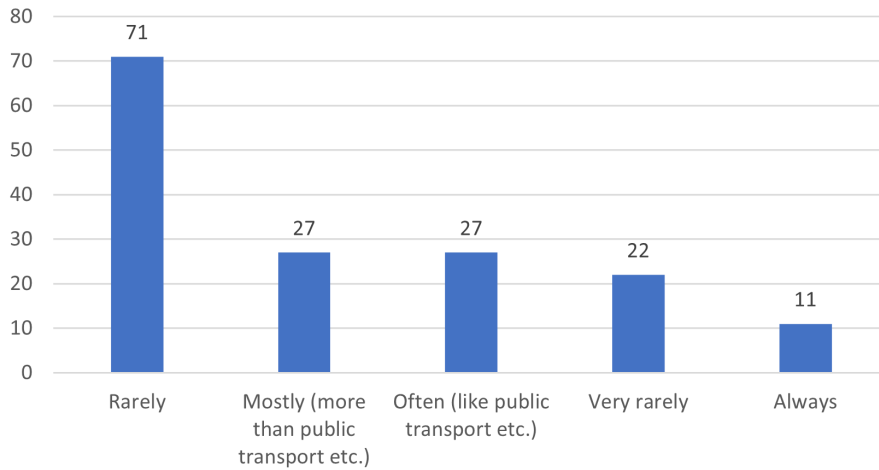


FIGURE 6. Use of the car compared to public transport for travelling around Prague.

The results in the following graph (Figure 5) show that the amount that most respondents are willing to pay for an hour of parking ranges from 0–45 CZK. The second largest group of respondents was in favour of 50–80 CZK per hour.

The last part of the questionnaire was focused on the use of P+R parking lots. The questionnaire showed that most respondents do not use P+R parking lots and those who do, do so rather exceptionally. There was also a choice of several reasons why they do not use this type of parking lots and under what circumstances they would start using them. The most frequent reason was another parking option in Prague or inconvenient location of these parking lots. The answers showed that the following 3 aspects would motivate the respondents to use these types of parking lots:

- Suitable location in relation to the destination;
- Convenient to reach the destination when transferring to public transport;

- Free parking.

The responses indicate that the most common problem that respondents have is the location of parking relative to where they need to go.

The purpose of the last question was to determine the frequency of private car use in Prague compared to public transport (Figure 6).

5. CONCLUSION AND FUTURE WORK

According to the available literature, dynamic parking is generally perceived as the most advanced method of parking regulation. By appropriately setting the dynamic price and the factors on which it is based, efficient use of existing parking spaces can be achieved. Tailoring parking regulation to the area is crucial. Pricing should be based on acceptable amounts, and the price can be seen as a tool to optimize the distribution of vehicles.

A very suitable solution is the use of a C2X system or the detection of license plate recognition in

a certain area and the connected virtual reservation of parking space. This results in significantly better vehicle navigation and a reduction in the so-called “wandering vehicle paths” that burden the road network of the area. In addition, the reservation of space and navigation also allows for the effective use of the space equipped with a charging station for electric vehicles.

Currently, Prague has a system of paid parking zones, which is no longer sufficient, and the parking situation is getting worse, especially in housing estates. The introduction of dynamic parking pricing as described in the article is currently hindered, among other things, by the technical parameters of the installed parking meters. The uploading of the price now takes several hours up to a day. Current legislation deals with the determining of the number of parking spaces and the parameters of these spaces. The methodology for calculating the price of parking in the relevant zone is defined. The issue of variable pricing is not addressed in the current legislation. Parking is also a very politically sensitive issue and often these are the main reasons that prevent a change in the regulatory system.

The survey could be summarized as follows: Most respondents either do not use vehicle for travelling to and inside Prague or use theirs or family vehicle. Number of respondents who use car-sharing services is quite low. Those respondents who live outside Prague more often use vehicle only to get to the city and for their transport around the city, they use public transport. They do not use vehicle inside the city.

Primary goal of the research was to ascertain what are the acceptable amounts of money to be paid for parking. Only few respondents are willing to pay more than 80 crowns per hour. Most of the respondents indicated that they would be willing to pay only symbolic amount of 20 crowns per hour. Second big group indicated price around 50 crowns per hour.

Next step of the research should be microsimulation using these data to simulate a behaviour of drivers based on the different prices of parking places. PTV Vissim – Traffic Simulation Software will be used for this simulation. The aim is to visualize a simulation of dynamic parking regulation for a selected part of the city.

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